Experience in continuous wave and long pulse operation of TESLA cavities cryomodules

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Abstract

The continuous wave operation scenario of TESLA cavities based accelerators is being investigated by different scientific facilities worldwide. The evolution from pulsed mode operation to constant operation requires not only redesign of cryogenic system or new design of high power RF amplifiers but also significant modifications of LLRF control system. In this paper the experiences concerning CW and LPO operation of the single cryomodule is presented. Development of the MTCA.4 HW platform based LLRF control system hardware, firmware and high level software towards long pulse operation are summarized.

Introduction

The scenario of CW and LP operation is being evaluated in DESY for last three years. The possibility of European X-FEL operation in long pulse operation is being checked. In order to achieve constant beam operation in designed and constructed linac setup some main limitations have to be taken into account:

- limited cryoplant capacity,
- limited power budget for cavities input couplers,
- lack of source of CW power for cavities,
- lack CW/LPO RF gun

As the CW capable RF gun is under construction the prototype of Inductive Output Tube (IOT) has been delivered and it is used during RF tests operation on single (8 cavities long) cryo-module. The main goal of conducted studies is evaluation of the cryo losses introduced by module and also quality of the RF field parameters controll during this kind of operation. Possibility of stable high gradient module operation with moderate cryo losses level (up to 20 W) is being verified. Successful tests will mean relatively inexpensive future XFEL upgrade towards constant beam operation.

CMTB setup for CW/LP operation

Cryo Module Test Bench (CMTB) is equipped with infrastructure needed for short and long pulse operation of single TESLA based cryomodule.

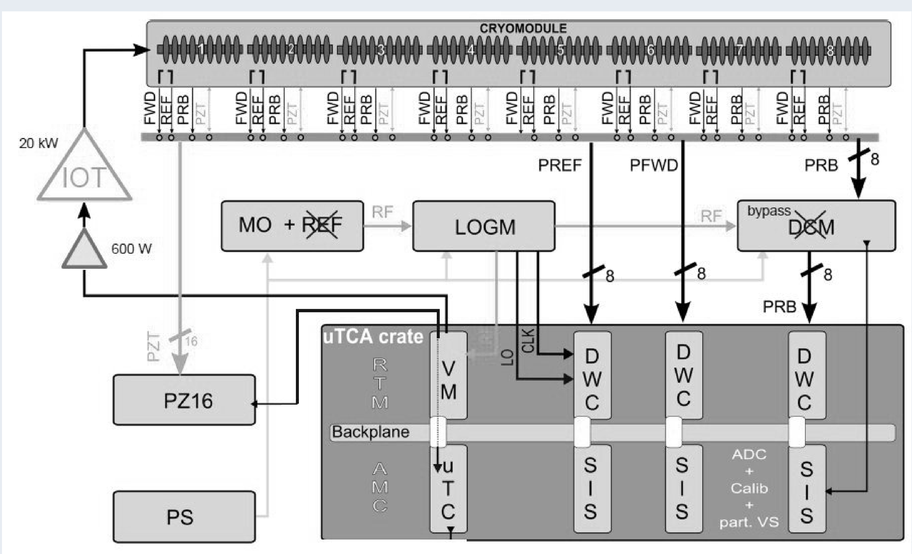

Figure 1: LLRF system - MTCA.4 realization

As for pulsing operation the LLRF system uses 10 MW klystron for CW/LPO installed IOT tube is being used. System consists also of piezo actuators driver box which allows for fine cavity tuning, LLRF system acquisition and controll hardware, cavity motors tuners and fundamental power coupler position regulation hardware (for fluent cavity loaded Q adjustment).

LLRF controller loop

The RF feedback for CW operation does not differ much from "standard" implementation.

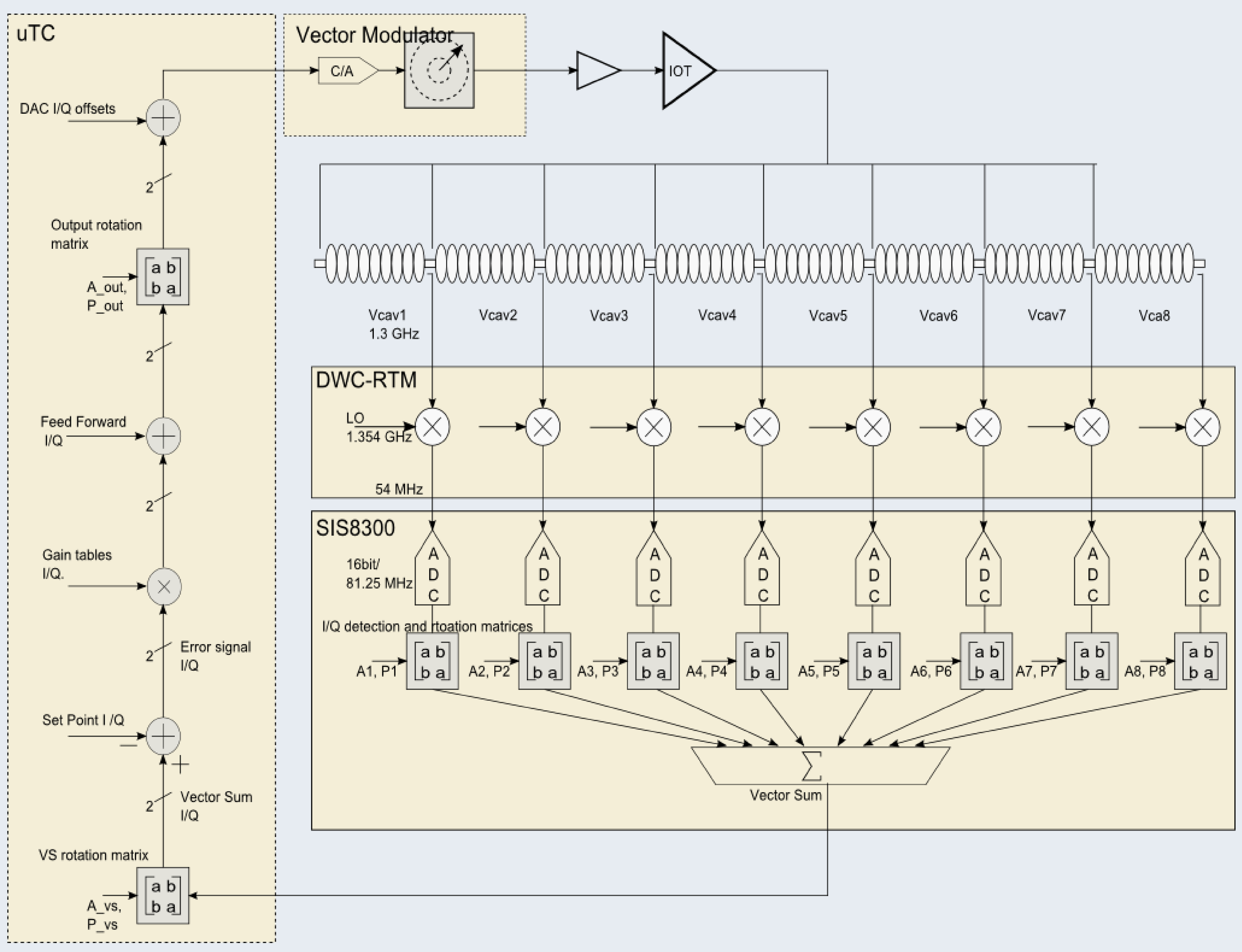

Figure 2: LLRF feedback loop overview

It can be realized as proportional or MIMO controller.

High Ql cavities control

In order to fulfill requirement of lower average power per coupler and low cryogenic losses the loaded quality factor of cavities in tested module has been increased. The Ql has been changed from 3e6 to 1.5e7 for each cavity. Such modification implies also significant bandwidth reduction (half bandwidth of 45Hz for Ql=1.5e7).

Piezo actuators loop

Piezo feedback loop realizes PI controller. The detuning is calculated as a phase difference between forward and probe signals.

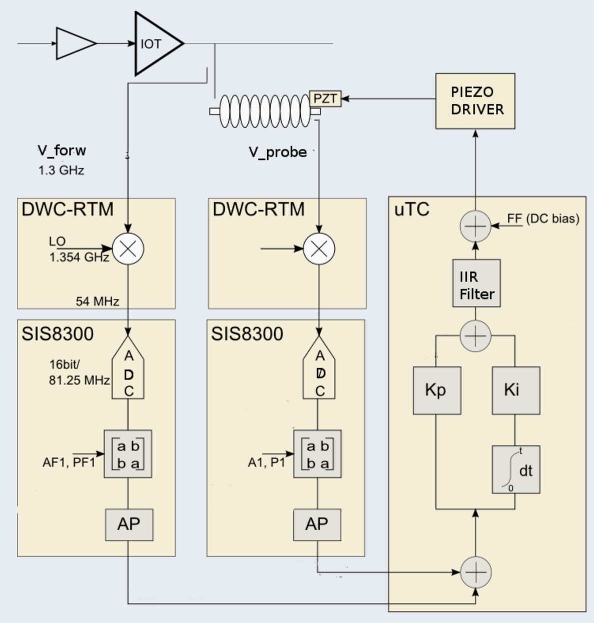

Figure 3: Piezo feedback loop overview

Measurement results

Best achieved (in loop) performance for CW operation was:

dA/A = 6e-5 ; dP = 0.01 deg

last measurements:

dA/A = 2e-4 ; dP = 0.5 deg

The cryo losses produced by whole module (for 8 cavities with gradient of 7MV/m operated CW) was at the level of **14W** (below 20W limit).

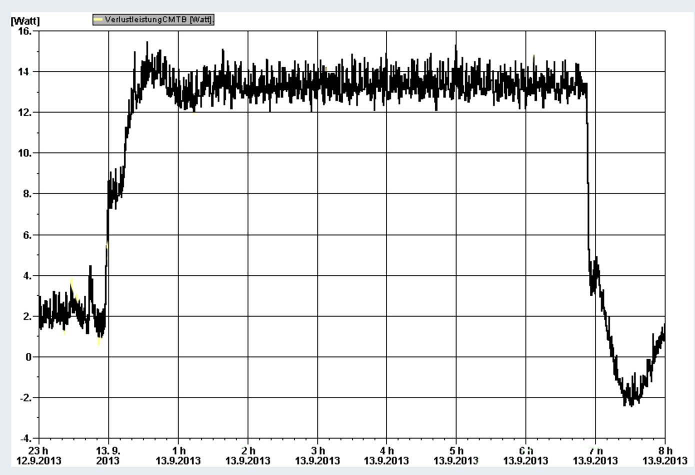

Figure 4: Cryogenic losses due to CW module operation

Challenges and future plans

Due to the presence of different microphonics sources (cryo-pumps, vacuum-pumps, others) precise cavities resonance frequency control is still challenging task. Implemented loops (LLRF, Piezo) have to be optimized for better disturbance suppression.

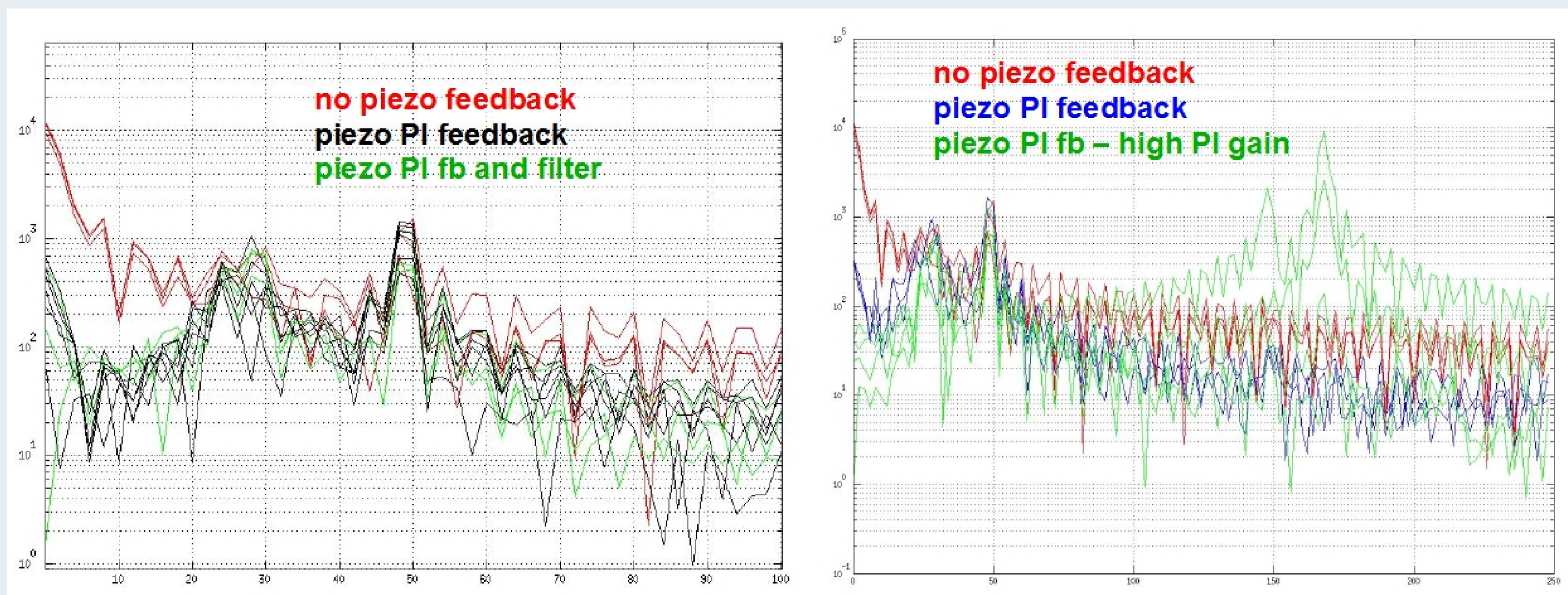

Figure 5: Cavity 1 detuning signal spectrum

Summary

Achieved field stability results are satisfactory (in loop - dA/A = 6e-5, dP = 0.01 deg) from the different experiments requirements point of view. Nonetheless to provide good quality regulation for higher gradients (up to 17 MV/m in case of XFEL upgrade) piezo feedbacks development will be continued to achieve better microphonics compensation performance.

Acknowledgment

We acknowledge the support from National Science Center (Poland) grant no 5593/B/T02/2010/39